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QUARTERLY PROGRESS REPORT NUMBER 1, 1 JANUARY-31 MARCH 1968.(U)

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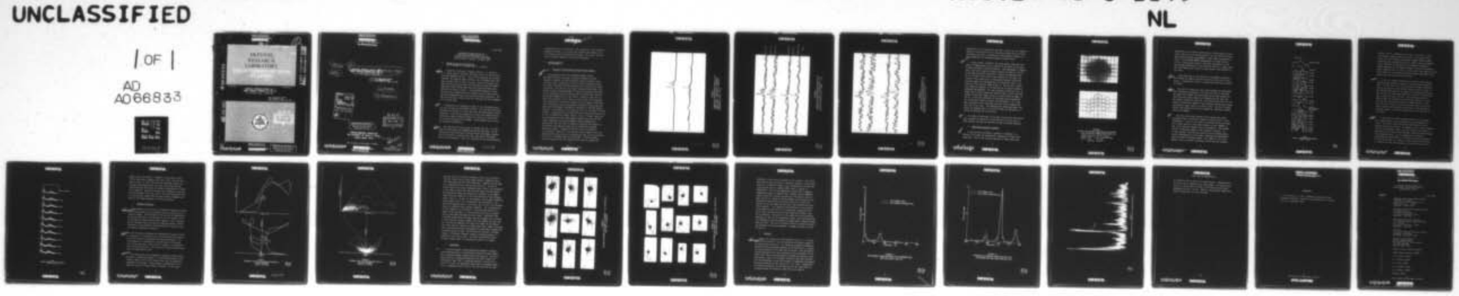

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QUARTERLY PROGRESS REPORT No. 1
UNDER CONTRACT N00024-68-C-1149 (U)

For the Period 1 January - 31 March 1968

NAVAL SHIP SYSTEMS COMMAND
Contract N00024-68-C-1149
Project Serial No. SF 1010316, Task 08515

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15 NAVAL SHIP SYSTEMS COMMAND
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QUARTERLY PROGRESS REPORT No. 1
UNDER CONTRACT N00024-68-C-1149 (U)
Project Serial No. SF 1010316, Task 08515
For the Period 1 January - 31 March 1968

A. AN/SQS-23 Digital FM Classifier
(K. W. Harvel, A. O. Herbst, and W. D. Howard)

(U) ~~FOUO~~ During the first week of January, Messrs. D. D. Gray and T. A. Carter flew to Key West, Florida, to remove the FM classifier from USS SARSFIELD (DD 837). This involved removing the two main cabinets, the Raytheon paper recorder, and the Sangamo Model 3500 tape recorder from the sonar room area, removing the Remote Servo Unit from the dry stores area, and removing the Defense Research Laboratory (DRL) cabling which had been installed between these units and the ship's circuits. The wide-band band-pass filters from the sonar preamplifiers were replaced with the sonar filters, and the preamplifiers were then restored to proper operation. The DRL truck returned to Austin with the classifier and test equipment on 15 January 1968.

~~(C)~~ Preparations were immediately begun for the forthcoming April sea trip on board the USS ROGERS (DD 876). The classifier and paper recorder were checked to be sure they were operating properly in the laboratory. The special preamplifier filters were checked individually and a special mounting bracket was installed on each filter to facilitate mounting on the ROGERS. On 29 February the sea trip was postponed indefinitely.

(U) ~~FOUO~~ The classifier was then set up to operate with the 1 in. data tapes recorded aboard the SARSFIELD during the 1967 trip. It was necessary to build interface circuitry between the Sangamo recorder and the classifier to provide zero time, sonar dwell, and target pulse to the classifier. Also, the circuitry for the wow-and-flutter

compensation had to be installed. Upon completion of the necessary playback interface, it was noted that repeated tape segments did not produce identical correlation envelopes. The reasons for this lack of playback capability are being investigated.

B. Systems Analysis
(S. P. Pitt)

1. Analysis of PAIR Doppler Classification Display

(U) During January 1968, Naval Undersea Warfare Center, San Diego Division, San Diego, California (NUWC-SD) and DRL decided to complete the PAIR classifier study by issuing a joint technical report containing all the conclusions generated during the study, along with the data analysis that had resulted in those conclusions. An outline of the report was generated during a conference at DRL, and apportionment of sections was made on the basis of the individuals who were involved with the particular analyses. The Systems Analysis part of the report, assigned to DRL, was concerned with analysis of the effects of pulse length (T), bandwidth (W), quantization accuracy and sampling rate for digital crosscorrelation processing, and the measurement of Doppler using up and down swept linear FM signals (including a simulation of the PAIR Doppler display). A description of the data base was also included in the DRL portion. A rough draft of the DRL portion has been generated and will be sent to NUWC-SD for comment shortly. Figs. 1 through 3 show some of the simulations of the PAIR Doppler display for stern and beam aspect submarines with various Doppler values (simulated by shifting the "up" and "down" correlation functions with respect to one another) and signal-to-noise ratios (simulated by adding appropriate noise). Signal-to-noise ratio here is defined as 10 log σ_S^2/σ_N^2, where σ_S^2 is the variance of the signal (echo) computed from the actual data (at very high S/N) and σ_N^2 is the variance for the noise computed from the actual data. It was concluded from this analysis that the display itself would be adequate for

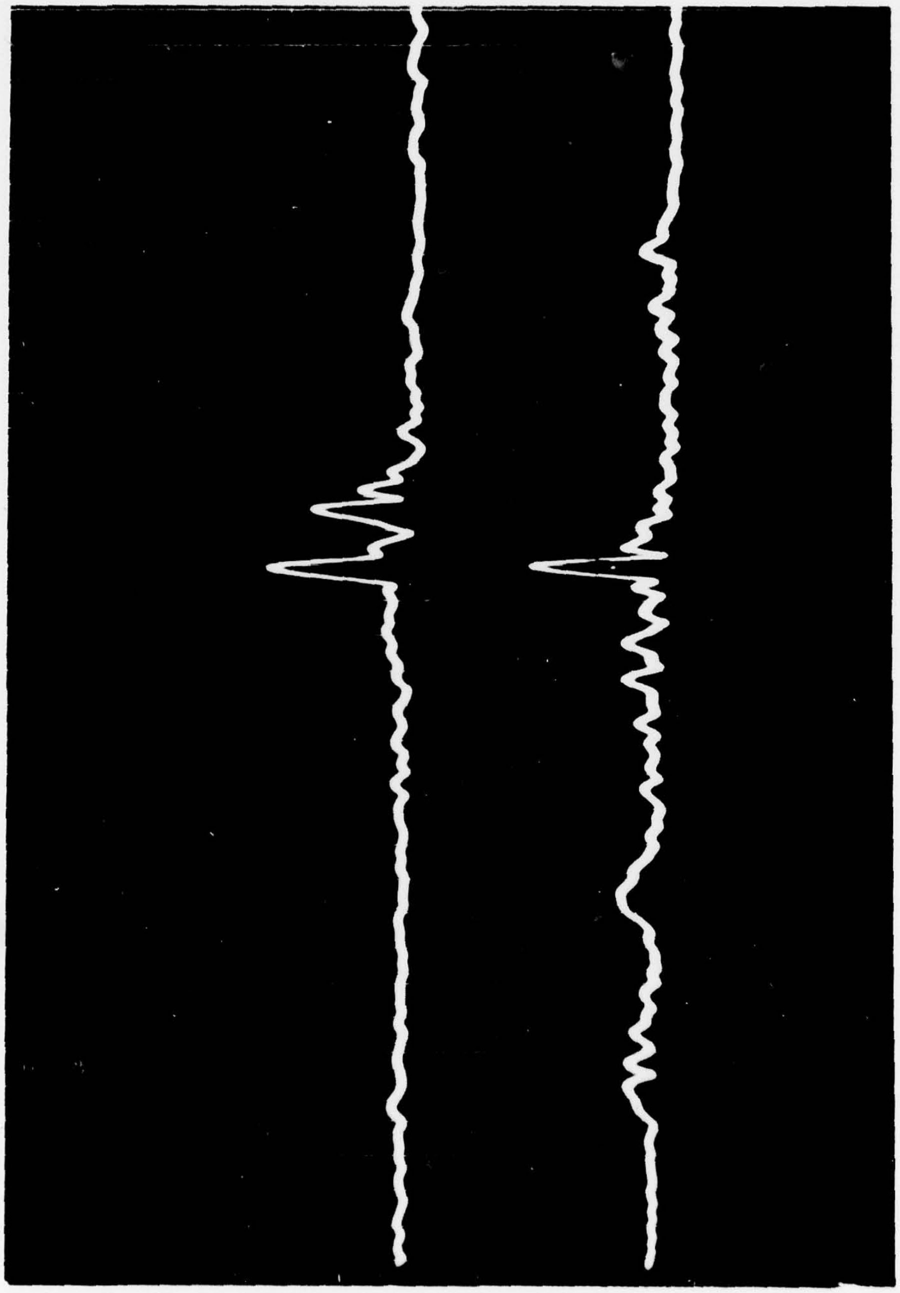

FIGURE 1
SIMULATED PAIR DOPPLER DISPLAY (U)
UPPER TRACE: BEAM ASPECT SUBMARINE
LOWER TRACE: BOW ASPECT SUBMARINE
HORIZONTAL SCALE: 2 kt/div

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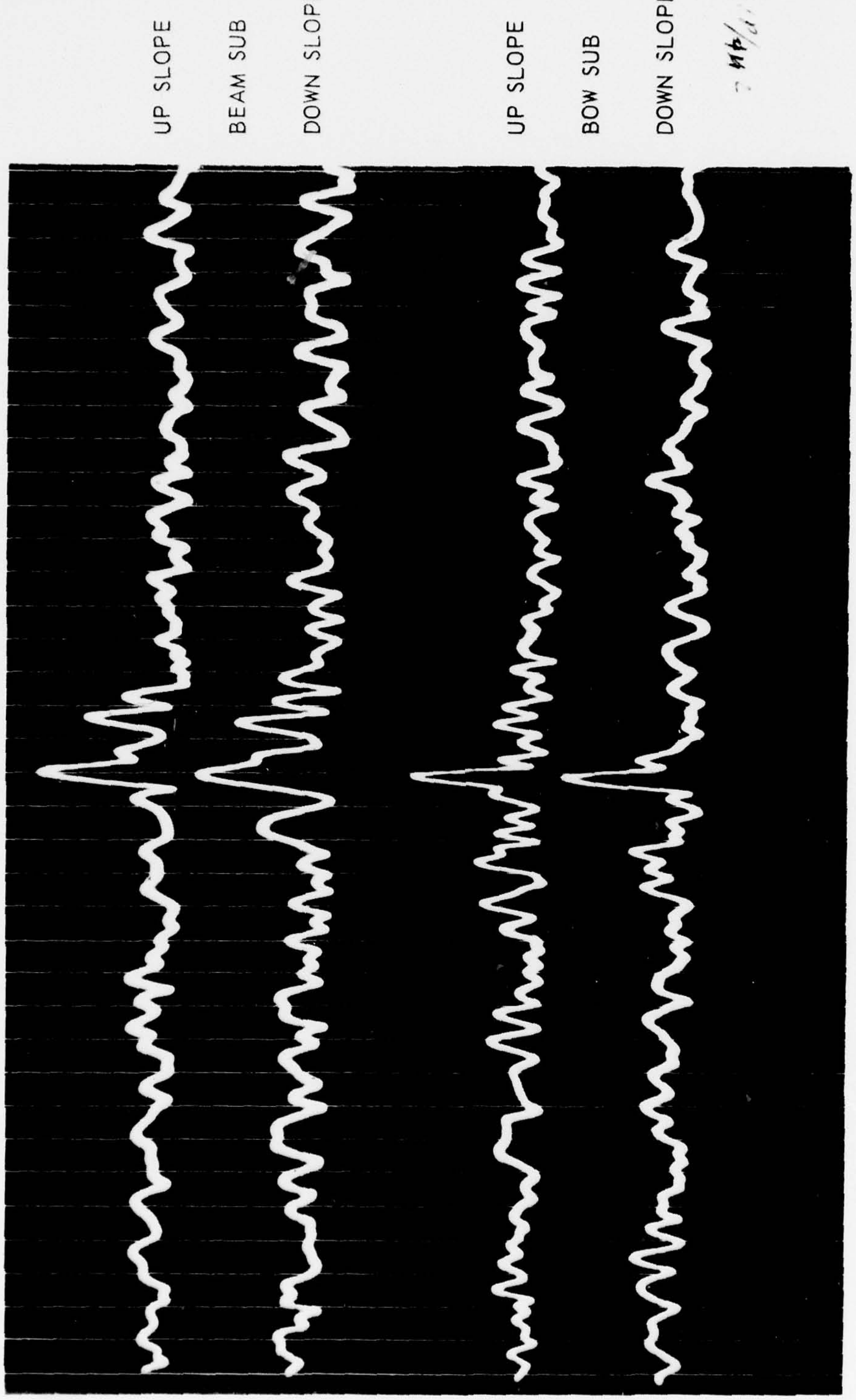

FIGURE 2
SIMULATED PAIR DOPPLER DISPLAY (U)
S/N RATIO AT INPUT TO CORRELATOR = 0 dB
SIMULATED DOPPLER SHIFT = +~~2 Hz~~ 0 kt

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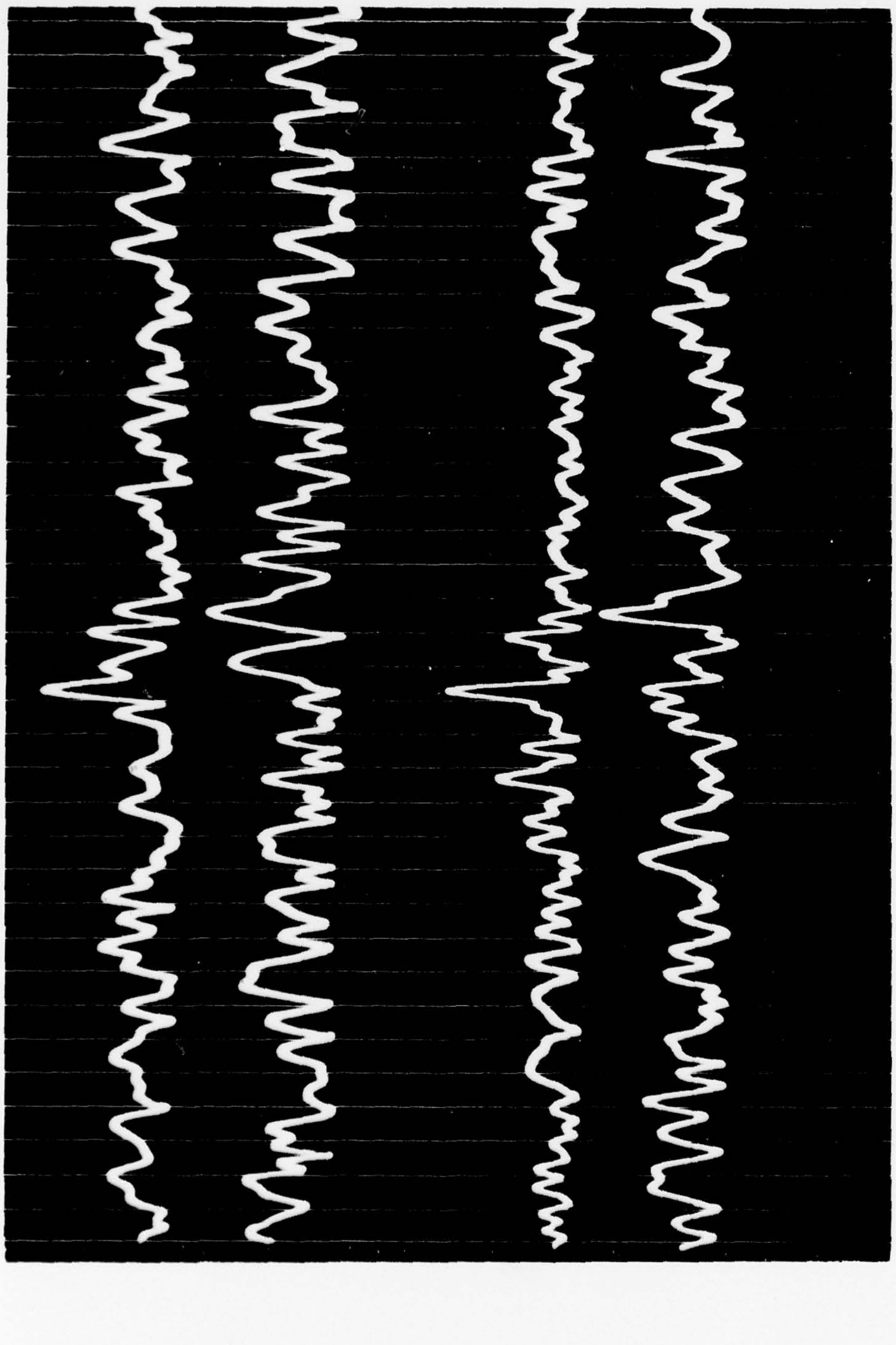

FIGURE 3
SIMULATED PAIR DOPPLER DISPLAY (U)
S/N RATIO AT INPUT TO CORRELATOR = -6 dB
SIMULATED DOPPLER SHIFT = +5 kt

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presentation of the information and that, at least for the submarine targets so far encountered, the similarity between the up and down correlation functions is sufficient to allow Doppler analysis of the information (for reasonable signal-to-noise ratios).

(C) A recent study, included in the joint report, deals with the effect of sampling rate on the location of the peaks of the reconstructed correlation function envelope. (The measurement of Doppler from a time shift requires accurate location of peaks in both the up and down correlation functions.) Because the sampling times are not related to the echo (or the structure of the echo), the location of the peaks of the reconstructed (analog) correlation functions might vary depending upon the particular choice. The results of the study are shown in Fig. 4. For Fig. 4a, a particular signal was sampled at 1.25 kHz and the correlation function generated and displayed. The same conditions existed for Fig. 4b except that the first sample was shifted (later) by 200 μsec with respect to the first sample of Fig. 4a, and so forth for Figs. 4c and 4d. In the D/A conversion for obtaining this presentation, the records were offset by exactly the same amount. It is seen that the peaks of the correlation function occur at exactly the same time in all cases. The sampling rate chosen represents very nearly the sampling rate to be used for PAIR, and therefore, no problem is foreseen for this process.

(C) It should be noted that all the data used for the joint report were processed in quadrature, essentially as it will be done in PAIR, whereas this had not been done by DRL in previous analyses.

2. Statistical Analysis of Echoes

(C) A study has been initiated to attempt to "identify," or separate, the random and deterministic components of echoes from submarines. Data at DRL include sequences of echoes taken from

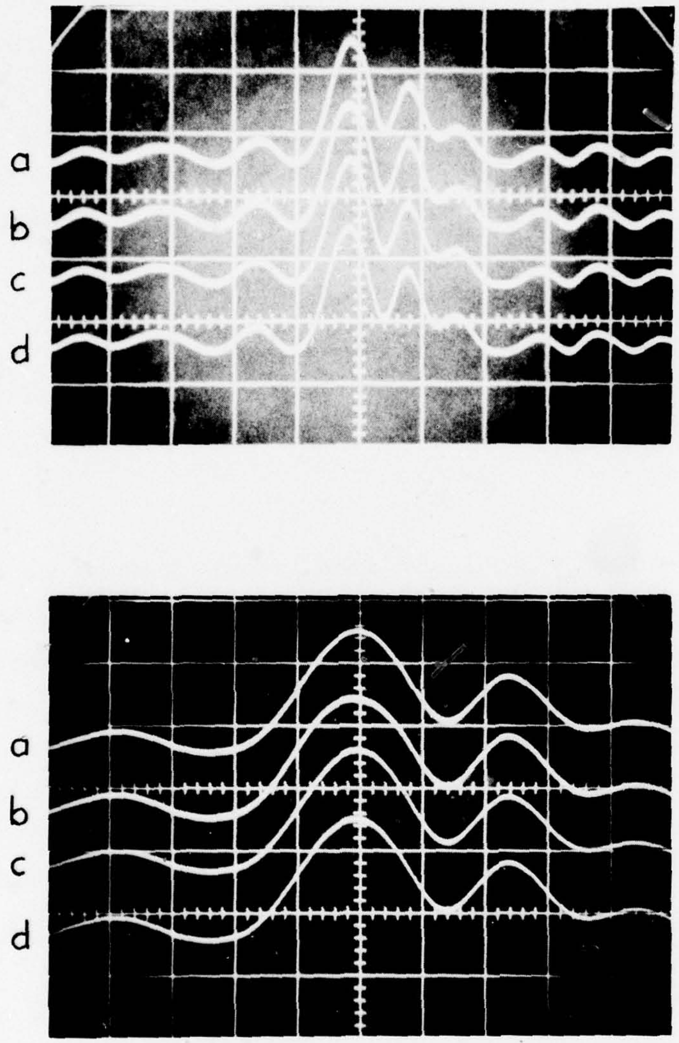

FIGURE 4
EFFECT OF RANDOM SAMPLING ON LOCATION AND SHAPE OF CORRELATION PEAKS (U)
LINEAR FM SLIDE: TW = 32, W = 625
SAMPLE RATE: 1.25 kHz IN QUADRATURE
SCALE: TOP: 5 msec/div
BOTTOM: 1 msec/div

submarines at near-constant aspect angles at high signal-to-noise ratios, where the time between echoes is on the order of 300 msec. These data were taken using ASPECT, a fleet sonar classification device. The standard ASPECT transmission is a train of short (0.5 to 5 msec) pulses spaced at 300 msec, the duration of the train being proportional to the round-trip time for a single pulse. The time between pulse trains was about equal to the duration of the train.

(U) ~~FOUO~~ Using these data it was possible to do ensemble statistics, the ensemble of samples being the returns from each of the short pulses. A program was written to perform the statistical analyses as follows.

(U) ~~FOUO~~ The peak of a particular data record (signal) was determined, and a threshold established as 1/n times the value of that peak. The epoch of the signal was then defined as the time between the first time the signal crossed that threshold and the last time the signal crossed that threshold. Each record was treated in this manner, and the first samples of the resulting records were assumed equivalent in sample space (or relative time). The first through fourth order statistics were then computed for equivalent samples across the ensemble.

~~(C)~~ The first set of data treated in this manner were echoes (envelopes) from a beam aspect submarine resulting from a 1 msec transmission. A plot of the values of the means across the ensemble is shown above the first twelve members of the ensemble in Fig. 5; the mean was computed from 57 such members. The dissimilarity of individual members of the ensemble is obvious. It is seen, however, that the mean function has two distinct peaks located approximately 4.6 msec apart, implying two deterministic paths of slightly different length. This length (11 ft if propagation time is two-way) corresponds closely with the distance

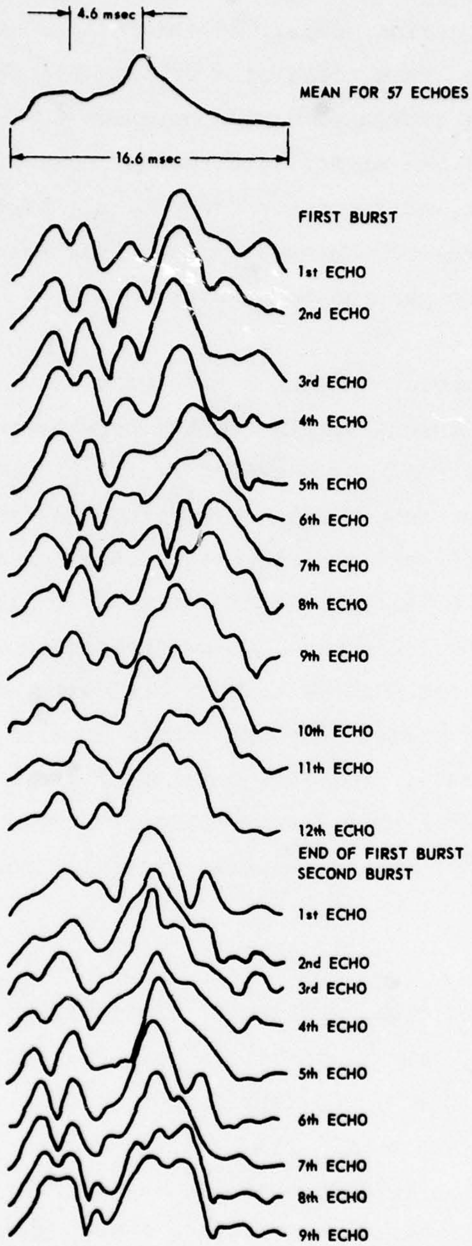

FIGURE 5
ENSEMBLE AVERAGE FOR BEAM SUB ECHOES (U)
ASPECT 1 msec PULSE

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from the side of a submarine to its sail. Of course, it also corresponds to several other paths which can be hypothesized (e.g., since the submarine maintained constant heading, speed, and depth, the second path could be a surface reflection phenomenon). Whatever the explanation, the apparent averaging of random components of the signal envelope to leave two reasonable peaks indicates that, at least for these ideal, high signal-to-noise ratio echoes, this ensemble processing provides meaningful information about the echo generation process.

~~(C)~~ In Fig. 6, ensemble statistics are shown for a bow aspect submarine under conditions similar to the beam aspect submarine case. For this case, only nine echoes from a single burst were used to calculate the mean function shown at the top of Fig. 6. The similarity between all the members is striking for this case and, in fact, the similarity holds for a total of 11 such bursts over a period of some 1 1/2 min. Using the same routine to define epoch, the lengths of mean functions computed for each burst of nine echoes varied only one sample interval, or 200 μsec, for the 11 bursts. For this particular case, the entire process appears to be highly deterministic. More data must be analyzed, however, before any reliable general conclusions can be reached.

(U) ~~FOUO~~ In searching for other meaningful statistics to describe the ensembles above, several possibilities were suggested and tried. The second, third, and fourth order statistics were computed along with the mean. It appeared, from a cursory examination of the consistent echoes, that the variance was highest at the points on the slopes of the envelope curves and near the peaks of the envelope curves. At the suggestions of Professor David Middleton and Professor C. W. Horton, curves were plotted to show the variance as a function of the mean and the variance as a function of the time derivative of the mean for each time

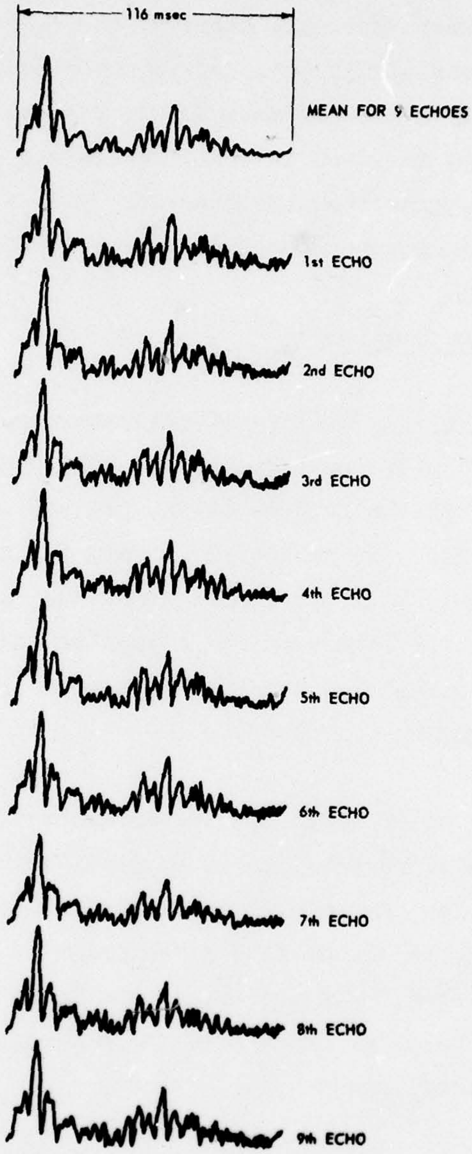

FIGURE 6
ENSEMBLE AVERAGE FOR BOW SUB ECHOES (U)
ASPECT 1 msec PULSE

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sample across the ensemble. Examples of each type of curve for the beam aspect submarine are shown in Fig. 7 and for bow aspect in Fig. 8. The curves show the described effect, the variance being highest where the slope of the mean function (and thereby the sensitivity to accurate determination of epoch) is the greatest. Both sets of data show a decrease in the variance at the peaks of the mean curve. The bow sub data show this to a much greater degree than the beam sub data, implying less power in the random component of the bow sub echoes.

3. <u>Quadrature Sampling</u>

(U) ~~FOUO~~ Investigation of the utility of quadrature sampling continued during this quarter with the immediate goal the publishing of at least two papers. The usefulness of the process is demonstrated by the ease with which the envelopes for all the signals used in the statistical analysis program were computed. Also, the quadrature components have been used for computing spectra, Hilbert transforms, crosscorrelation and autocorrelation functions, and instantaneous frequency (or phase).

(U) ~~FOUO~~ The obtaining of envelope and instantaneous frequency allows a computation of a different type of spectrum which would appear to be very useful for analyzing time-limited FM signals, i.e., the assigning of an amplitude to a given range of frequencies over a given time span. The process is similar to a probability density function analysis. This process is presently under analytical and experimental study.

~~(C)~~ The availability of the quadrature components allows another treatment of narrow band signals: a polar representation of the signals, namely, X(t) vs Y(t), where X and Y are the quadrature components of the signal. This provides a representation for a signal for which the length (time) is removed. On this polar

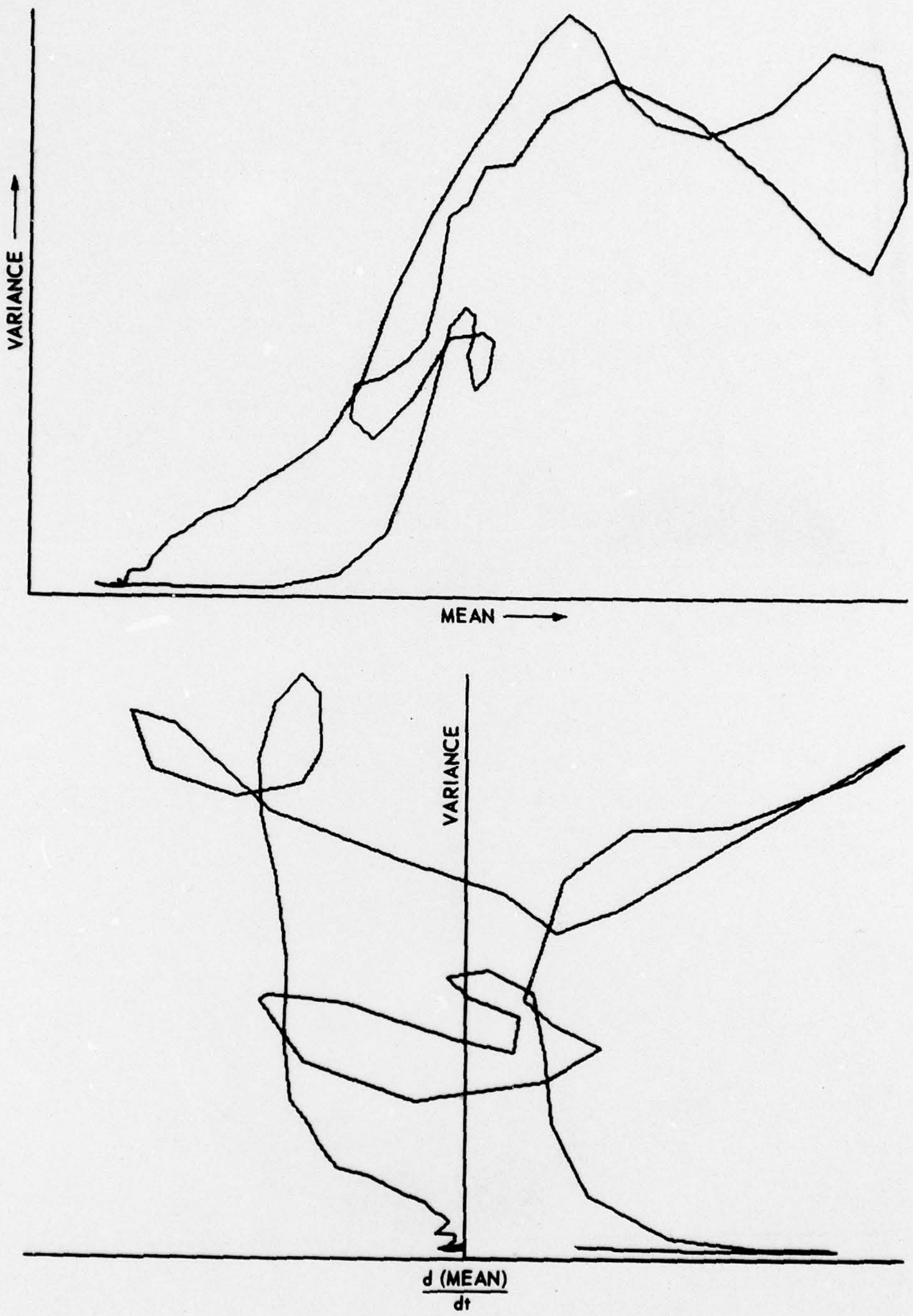

FIGURE 7
ENSEMBLE STATISTICS FOR BEAM SUB ECHOES (U)
57 ECHO ENSEMBLE
ASPECT 1 msec PULSE

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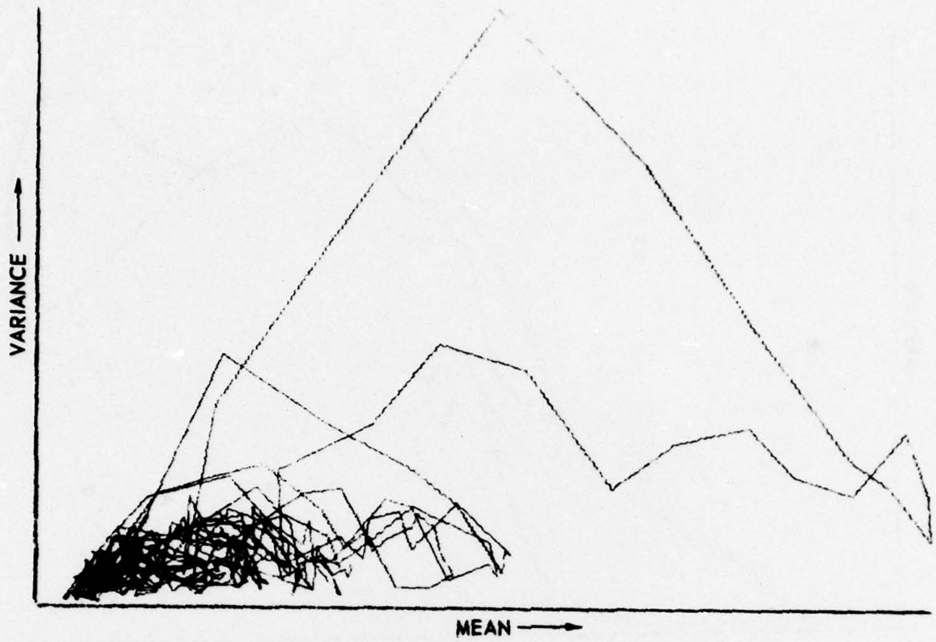

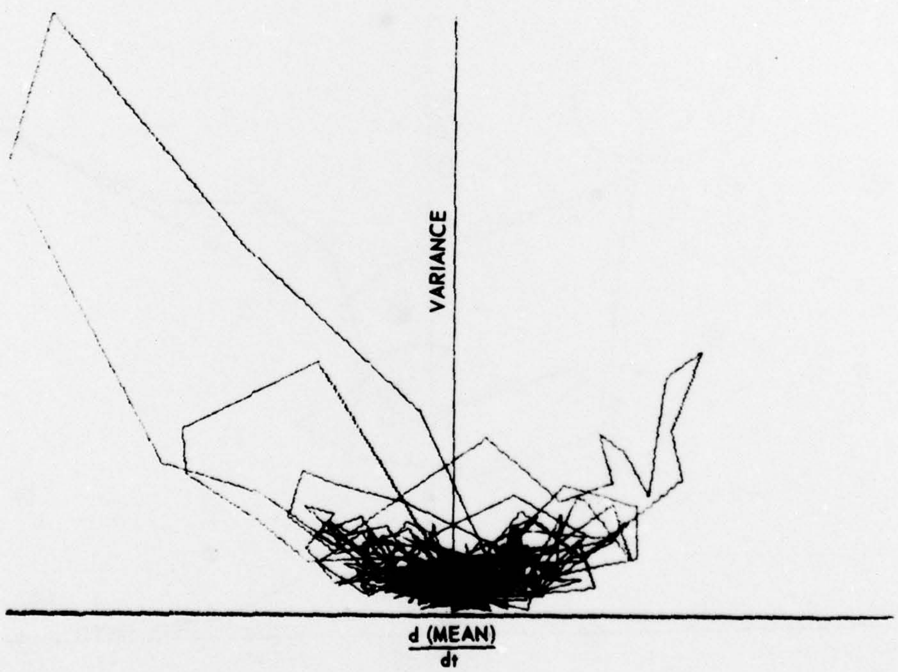

FIGURE 8
ENSEMBLE STATISTICS FOR BOW SUB DATA (U)
NINE ECHO ENSEMBLE
ASPECT 1 msec PULSE

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display, the value of signal envelope is given by the distance from the center, and the phase angle becomes a geometric angle with some arbitrary (but fixed) reference. Examples of this type of a representation are shown in Figs. 9 and 10. In Fig. 9, echoes from the bow aspect submarine shown in Fig. 6 are displayed in the order in which they were received (about 300 msec apart). The similarity between the functions is striking, as one might expect from the similarity of the time structure of the envelopes shown in Fig. 6. In Fig. 10, the sequence of beam aspect submarine echoes shown in Fig. 5 are displayed in the same manner. The similarity between echoes is not there, and, in fact, the waveforms take on a different (more rounded) character. The interpretation of this character is as follows: A constant phase angle for a "bump" in the envelope of a time function would give a straight line at some angle emanating from the center. Deviations from a constant phase across the bump cause the straight line to become a curve; the more change in phase, the more rounded the curve will be. For the bow submarine, the phase (as judged by the width of the loops) does not change by a large amount over a bump, indicating that no interfering returns (multipath) of significant strength are occurring during the bump. For the beam sub, however, the phase change is continuous, implying strongly overlapping returns, as expected at this aspect angle. The polar representation then provides another means for analyzing the nature of a target.

4. Chatterbox

(C) A novel technique (called Chatterbox) designed to improve either detectability or classification accuracy of sonar signals was introduced by Bendix Company during this quarter. The technique utilizes a square-wave-modulated sine wave (2 msec "on" followed by 2 msec "off", alternating between on and off for a total of 30 msec), the hypothesis being that an elongated target (e.g., a submarine) would "fill in" the off times for the echo,

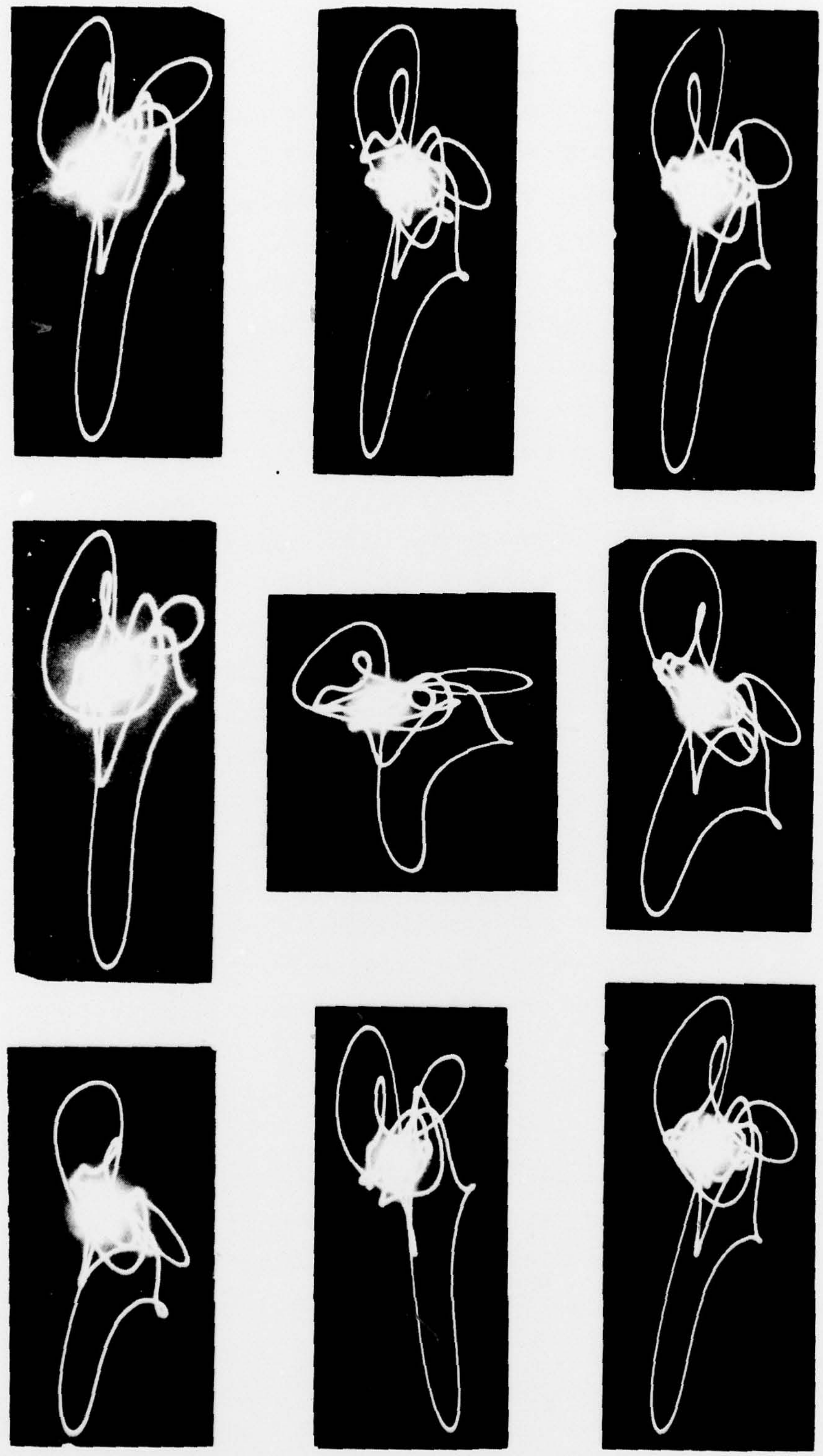

FIGURE 9
POLAR PATTERNS FOR BURST OF ASPECT 1 msec PULSES (U)
BOW ASPECT SUBMARINE

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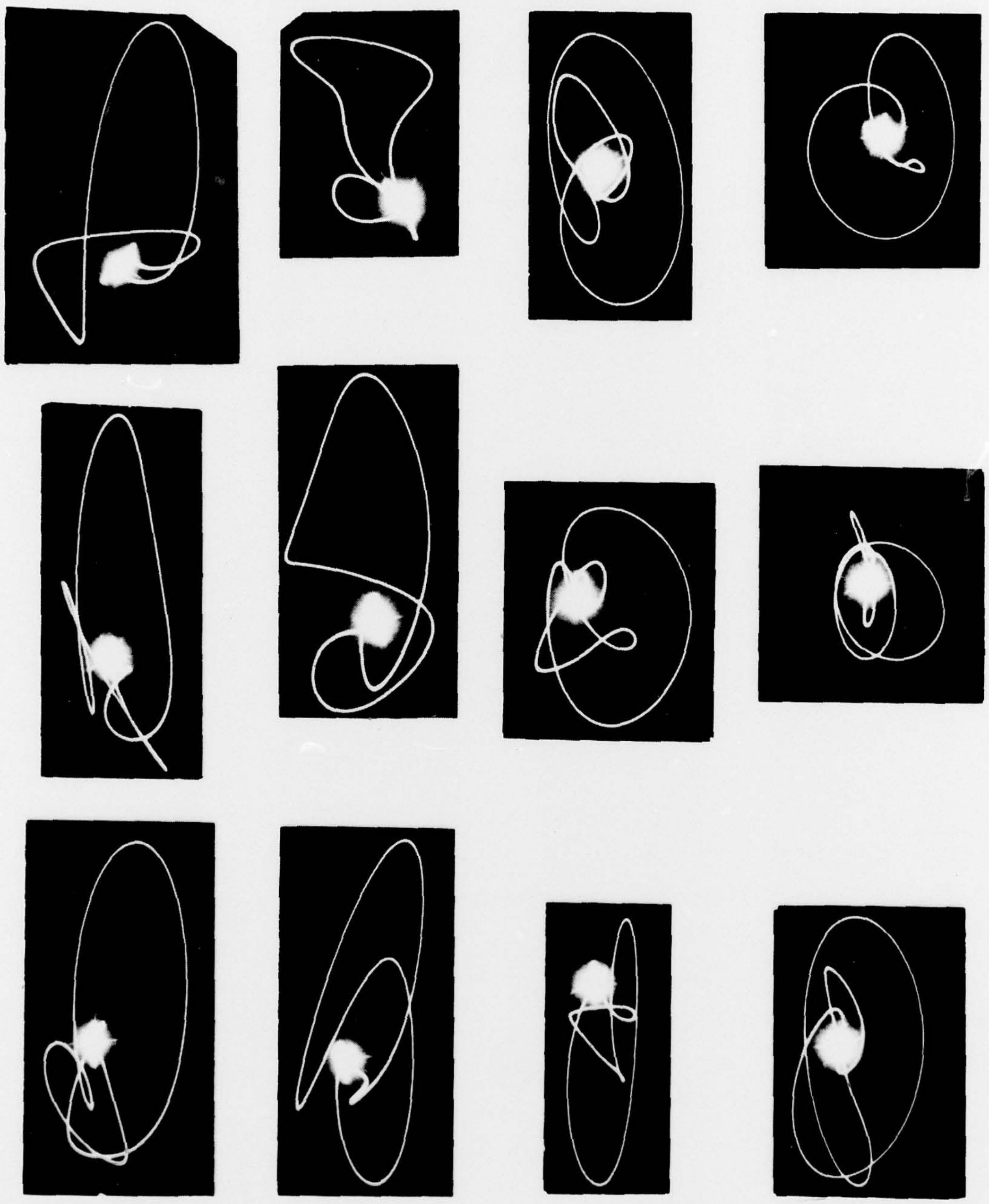

FIGURE 10
POLAR PATTERNS FOR BURST OF ASPECT 1 msec PULSES (U)
BEAM ASPECT SUBMARINE

producing a near-constant frequency at the receiver. This would mean that the echo would have a different frequency spectrum than either the transmitted signal or the reverberation, as described in letter Ser L-54 of 14 March 1968, from K. W. Harvel to SHIPS 00V1C. To test this hypothesis, echoes from a submarine supplied by Bendix on magnetic tape, recorded from an AN/SQS-10 sonar system, were spectrum analyzed with the results shown in Figs. 11 and 12. Figure 11 shows examples of the spectra of the envelopes of reverberation and echo, while Fig. 12 shows the spectra of the raw signal for the same, only averaged over individual spectra. It is apparent that differences in the spectra of reverberation and echo for the Chatterbox transmissions are quite small, indicating that the gain expected by Bendix could not be achieved. The spectra of the echoes are also essentially identical to that for the transmitted signal, also indicating that the "filling in" process expected by Bendix from a submarine target does not occur. This can be further verified by simply observing the envelopes of the raw waveforms, an example of which is shown in Fig. 13.

5. Visitors

(U) During this quarter Dr. David Middleton and Dr. C. W. Horton spent a brief period of time in conference with various groups of the Signal Physics Division. Dr. Middleton presented preliminary results from his analytical modeling of the submarine as a target, and several aspects of the model were discussed. Data analyzed by Systems Analysis Section were presented to the consultants in the light of the model, and discussions concerning the meaning of the data ensued. Some of the ensemble statistics data were available for this discussion, as well as the paper on quadrature processing[1], which was presented at that time by Mr. O. D. Grace. Suggestions for further processing of sonar data and for the construction of a physical model for studies at Lake Travis were made by

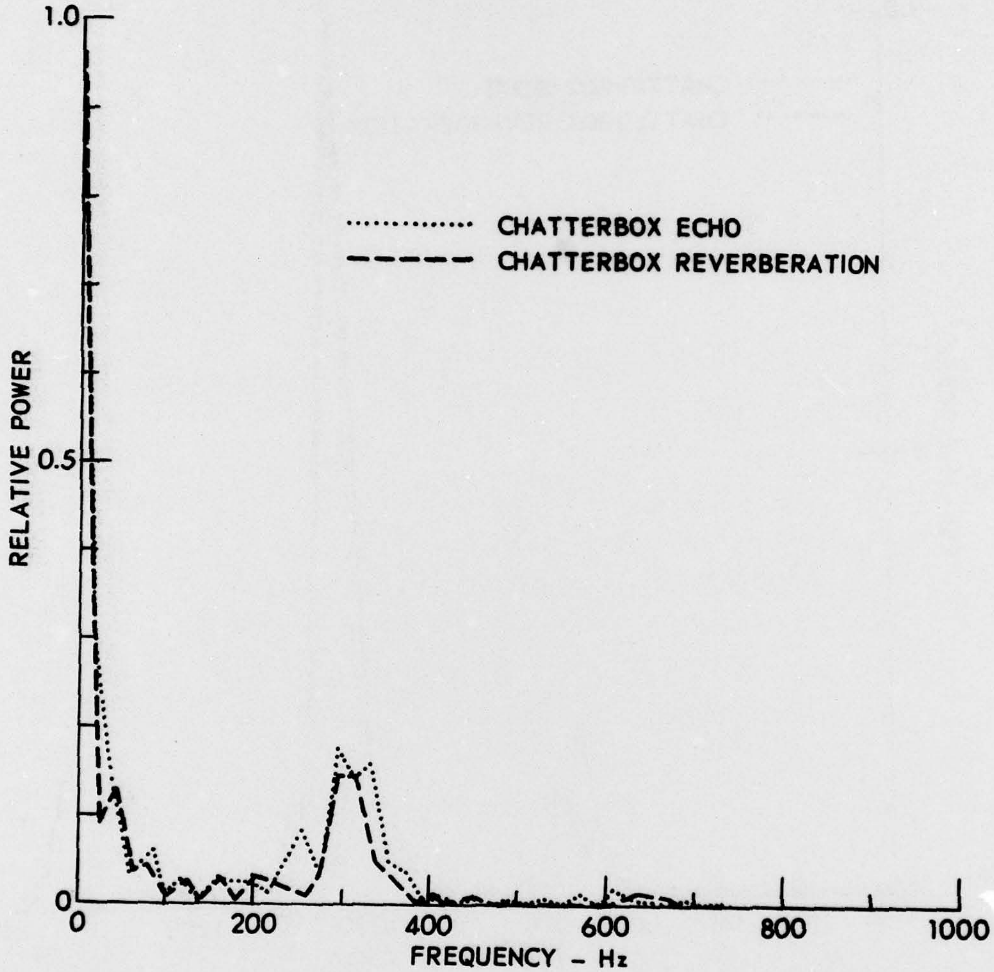

FIGURE 11
CHATTERBOX POWER SPECTRA FOR REVERBERATION AND ECHO ENVELOPES (U)

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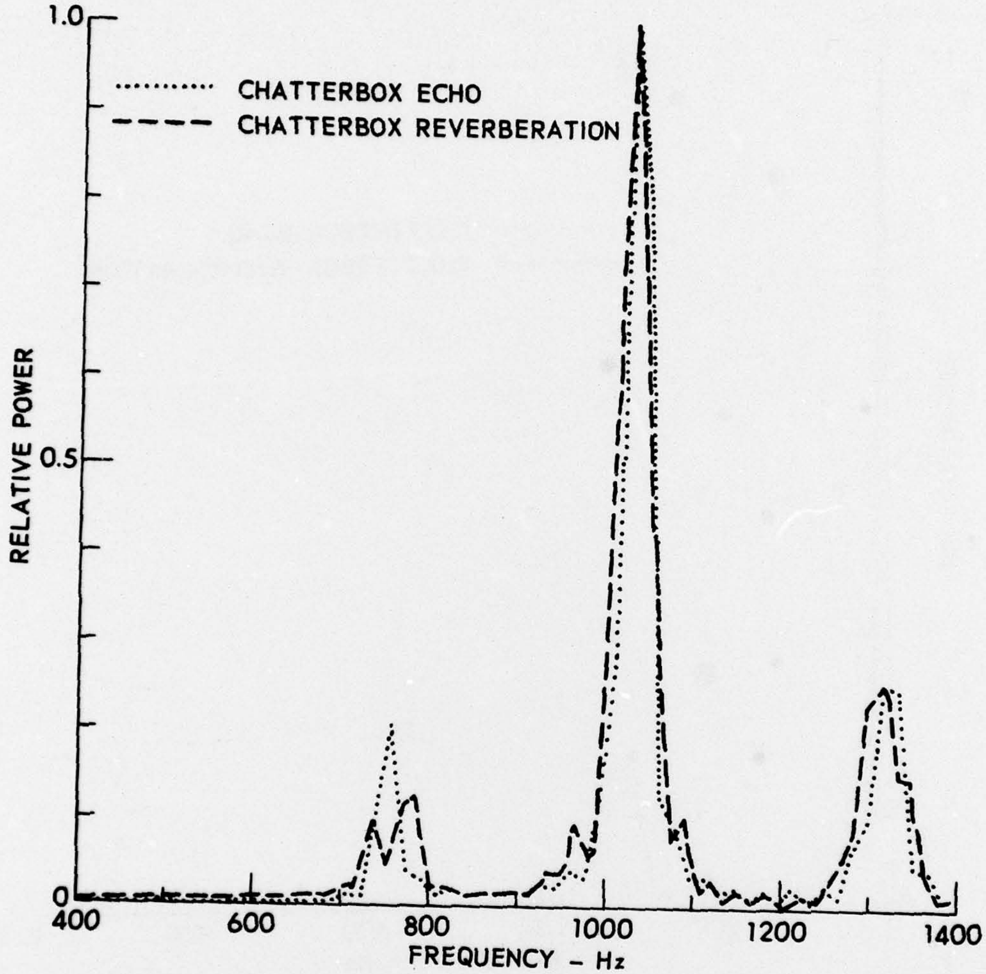

FIGURE 12
AVERAGE CHATTERBOX POWER SPECTRA FOR REVERBERATION AND ECHO RAW DATA (U)

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FIGURE 13
REVERBERATION AND ECHO ENVELOPE FOR CHATTERBOX TRANSMISSION (U)

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Dr. Middleton and Dr. Horton and others present. Implementation of most of these suggestions has either begun or is being carried out; e.g., see the plots of Figs. 7 and 8 and the polar representations of Figs. 9 and 10. However, statistically significant amounts of data have not been processed.

REFERENCES

1. O. D. Grace and S. P. Pitt, "Quadrature Sampling of High Frequency Waveforms," submitted for publication to J. Acoust. Soc. Am. in February 1968.

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